LINEAR IR CORRECTIONS

J.-P. Koutchouk,
CERN, Geneva, Switzerland

Abstract

This is a brief report of the status of the CERN studies on linear corrections (orbit and coupling) at the time the US/LHC agreement was passed. I have updated certain of the conclusions whenever possible.

1 ORBIT CORRECTION

1.1 Criterion for the Arc Correction

Given the alignment tolerance which can be either estimated or deduced from LEP measurements, the nominal strength of the arc correctors is set at a level where the probability of exceeding the maximum is 'small', i.e. less than 8%[1]. This will happen at a few places around the machine and will be solved by closing the orbit perturbation at π or further away. These exceptions are allowed as the mechanical aperture at top energy is large in the arcs. This approach allows a better filling factor of the collider. The corresponding criterion for the integrated strength of the dipole corrector per Tesla of integrated gradient strength of the near-by quadrupole is:

$$0.0022 \text{ Tm per Tesla} \tag{1}$$

1.2 Case of the low-β Triplet

There are two MCBX orbit correctors per triplet, each of them providing 1 Tm (optionally 1.5 Tm). The arc criterion is therefore fulfilled at the 20% (30%) level. This is even optimistic as the closed orbit must be corrected **simultaneously** for the two beams with two correctors. The efficiency of each corrector is thereby reduced.

This was identified and accepted [2] with special provisions:

- we reserve the MCBX's for the correction of the misalignment of the MQX's, i.e. do not use it for beam separation, spectrometer compensation..., except for very small adjustments.
- the alignment tolerances of the MQX are much tighter than elsewhere: 0.3 mm maximum displacement for one quadrupole block, 1 mm maximum for a coherent displacement of a whole triplet [3],
- continuous monitoring of the MQX positions with a stretched wire lodged into a hole in the concrete to straddle the whole insertion,
- quasi 'on-line' realignment with motorized jacks.

1.3 Conclusion

The triplet requires special care. Increasing the strength of the MCBX to the maximum achievable is worth the effort as it will make operation simpler and thereby more efficient at collision time. A rigid triplet arrangement relaxes the alignment tolerances. A precise beam-based measurement of the magnetic axes (K-modulation) would certainly be very helpful.

2 COUPLING CORRECTION

2.1 Relative Importance of the Coupling Sources

We assume a_2 corrected in the arcs. The remaining sources of coupling are mainly the tilt of the quadrupoles: Arc, Matching Sections and Low-β Triplets. Assuming a rms tilt angle of 1 mrad, the respective contributions to the coupling vector c are, for LHC version 2 [4]:

Arc Quadrupoles	(13.6 +i 1.9)ϕ_{rms}
MS Quadrupoles	(6.8 + i 16.5)ϕ_{rms}
Triplets	(93.7+ i 165)ϕ_{rms}

c is given by the quadratic sum of the perturbations, where ϕ is the tilt and the other symbols have their usual meaning:

$$c = \phi_{\text{rms}} \sum^{\oplus} \frac{1}{\pi} \sqrt{\beta_x \beta_y}\, K l\, e^{i(\mu_x - \mu_y)} \tag{2}$$

The triplets are by far the largest potential source of betatron coupling. This qualitative conclusion surely still applies for the present LHC version.

2.2 Requirement for the Triplet Alignment

In order for the triplet quadrupoles to produce a manageable coupling, it is necessary to align them with respect to each other 10 times better than the arc quadrupoles. This requirement (0.1 mrad rms) seems achievable [5]. The module of the coupling vector (all sources) is then estimated to be 0.03 rms, i.e. a usual value for accelerators.

If the triplet can be made 'rigid', it becomes almost insensitive to tilts: a whole triplet tilted by 1 mrad only contributes to $|c|$ by less than 0.003.

2.3 Requirement for the Quadrupole Twist

A quadrupole twist causes about 20 times less effect than an equivalent tilt. The 2 mrad observed on one of the HGQ should not be a problem.

2.4 Coupling Correctors

The strength of the foreseen MCQS correctors is 30 T/m $\times$ 0.5 m. It can correct tilts of 1.6 mrad in the worst case where the tilts are correlated with the gradient signs. This is largely sufficient and leaves some reserve for the correction of remote sources.

2.5 Other Effects

Orbit and dispersion coupling have not been considered so far.

2.6 Conclusion

The skew corrector foreseen in the triplet corrector package appears largely sufficient. The beam dynamics is however so sensitive to random tilts of triplet quadrupoles that they must be very tightly aligned. The experience of LEP commissioning shows that large coupling causes the loss of beam control by fooling the instrumentation. A ‘rigid’ triplet is almost immune against tilts.

3 REFERENCES

[1] J. Miles, LHC Project Note 43, 1996.
[2] Minutes of the Parameter and Layout Committee # 11, 1996.
[3] S. Weisz, LHC Project Note 59 (1996).
[4] J.P. Koutchouk, LHC Note 306 (1994).
[5] T. Taylor, private communication, 1994.